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Imperative and Profound Regulatory Efficacy: Engineering Panacea for Flood Mitigation in Lower Niger Floodplain/Riverine Communities, South-South Nigeria

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ABSTRACT: The Niger River and its flow channels constitute major cultural, drainage, and socioeconomic resources for riverine communities. However, widespread degradation of river valleys and floodplains in Nigeria has increased flood risks, particularly in the Lower Niger and Niger Delta. This study examined the causes, effects, trends, and control measures associated with flooding in Delta State floodplain communities. It analyzed rainfall patterns in the Niger River Basin, Niger River flow characteristics, population growth and urbanization trends in Nigeria from 1950 to 2023, and waste management practices. The findings revealed high annual rainfall across the Niger River Basin, with river flow and wet-season discharge strongly influenced by rainfall. Population growth, urbanization, infrastructure development, inadequate environmental conservation, and poor waste management have accelerated the degradation of river channels and floodplains. These conditions increase surface flow into adjacent low-lying areas, intensifying annual flooding. Flooding in Delta State was therefore attributed to the combined effects of intense rainfall, degraded river systems, and inadequate implementation and enforcement of environmental protection and urban planning policies. Effective flood mitigation requires restoration of the Niger River system, sustainable waste management, stronger enforcement of environmental regulations, improved administrative controls, and community-based behavioral management strategies.

KEYWORDS: Population growth; urbanization; infrastructures; niger river; floodplains; rainfall

1. Introduction

The Niger River and its tributaries and distributaries constitute important cultural, socioeconomic, technological, and political resources for riverine communities [1–4]. River valleys support agriculture through nutrient replenishment and irrigation, provide food and raw materials, facilitate navigation and communication, create employment, and supply water for domestic use, livestock, and hydropower generation [1, 2–5, 7–9]. Historically, water transportation also supported trade, commerce, administration, and the movement of people and goods, contributing to the establishment and expansion of numerous settlements along the Niger River and its associated flow networks [10]. However, increasing population, urbanization, infrastructure development, resource exploitation, and inadequate implementation of environmental and waste-management policies have progressively degraded river channels and floodplains. Such degradation reduces their natural capacity to convey and temporarily retain water, thereby increasing flood risks in the Lower Niger and Delta State floodplain communities.

The historical development of settlements along the Niger River was closely associated with trade, migration, fishing, transportation, and administrative activities [11]. Their socioeconomic potential subsequently stimulated population growth and transformed many riverine settlements into major commercial and urban centers [10–13]. Nigeria has experienced one of the world's highest rates of urbanization [14, 15], with important riverine centers developing along the Niger River and its tributaries [16]. Population growth and rural-to-urban migration have consequently increased demand for housing, transportation, schools, healthcare facilities, commercial areas, and other infrastructure [6, 17–22]. Between 2012 and 2022, Nigeria's urban population increased from 45.25% to 53.52%, while continued urban growth is expected to place further pressure on land and infrastructure [20–22]. Population growth, urbanization, urban expansion, and infrastructure development are therefore closely interconnected [23].

Infrastructure development can substantially modify natural hydrological processes. Vegetation removal, land clearing, soil filling, compaction, and construction reduce soil permeability and infiltration while increasing surface runoff. Impervious surfaces, including roads and rooftops, further accelerate runoff toward drainage channels, rivers, and low-lying areas [24]. These effects are particularly important in the Lower Niger and Niger Delta, where many communities occupy low-lying floodplains only a few meters above sea level. Consequently, poorly regulated development within river channels and floodplains can obstruct natural flow pathways and increase the likelihood and severity of flooding.

These anthropogenic pressures interact with the high rainfall characteristics of the Niger River Basin. As shown in Table 1, rainfall varies considerably among the countries within the basin, with Nigeria recording a mean annual rainfall of 1,185 mm within its basin area [1–3]. The Niger Delta receives even higher rainfall, with a reported mean annual value of approximately 2,185 mm, while Delta State receives approximately 1,785 mm annually [25–31]. Rainfall is concentrated primarily between May and October. The combination of intense seasonal rainfall, low-lying terrain, expanding impervious surfaces, and degradation of natural flood-storage areas therefore increases hydrological pressure on the Niger River and its associated flow networks [32, 33]. Flood risk is further intensified by the degradation and occupation of floodplains, which normally function as temporary storage and flow-buffer zones. Flooding occurs when river discharge exceeds channel conveyance capacity, particularly where channels are constricted, obstructed, or characterized by bends and meanders [24, 34]. This problem is particularly important in the Niger Delta because of its low-lying fluvial terrain and dense network of waterways [6]. Population growth, urbanization, intense rainfall, and climate-related changes have further increased flood vulnerability [17, 19, 21, 22, 24, 35].

Table 1. Hydrologically active area and rainfall distribution within the Niger River Basin by country.

Country	Total Country Area (million km²)	Area within Basin (km²)	Share of Basin Area (%)	Country Area within Basin (%)	Annual Rainfall within Basin Area (mm)		
					Minimum	Maximum	Mean
Benin	0.114	37,500	2.5	33.0	735	1,255	1,055
Burkina Faso	0.274	58,500	3.9	21.4	370	1,280	655
Cameroon	0.475	66,000	4.4	14.0	830	2,365	1,330
Chad	1.284	15,000	1.0	1.2	865	1,195	975
Côte d'Ivoire	0.322	18,000	1.2	5.6	1,316	1,615	1,466
Guinea	0.246	69,000	4.6	28.1	1,240	2,180	1,635
Mali	1.240	454,000	30.3	36.6	45	1,500	440
Niger	1.270	357,000	23.8	28.1	0	880	280
Nigeria	0.924	424,500	28.3	45.9	535	2,845	1,185
Total	**6.149**	**1,499,500**	**100.0**	—	—	—	—

Inadequate urban planning and environmental regulation have also contributed to uncontrolled development within river corridors and floodplains [19, 20, 22, 36]. Approximately 49% of Nigeria's urban population has been reported to live in slum conditions [6, 37]. In several Lower Niger communities, residential, commercial, industrial, religious, and transportation infrastructure has increasingly occupied natural drainage corridors and floodplains [24, 34]. Poor solid-waste management further compounds this problem because accumulated waste and sediment can obstruct drainage channels and river systems, reduce their conveyance capacity, and divert water toward adjacent low-lying areas. These processes interact with population density, urban expansion, infrastructure exposure, and rainfall variability to increase flood occurrence and impacts [34, 38, 39].

Flooding has consequently become a major environmental and socioeconomic challenge in Nigeria [34, 39, 40]. International experiences demonstrate that floods can cause substantial mortality, displacement, infrastructure damage, and economic losses [41, 42]. Nigeria has experienced similarly severe events. The 2012 flood affected extensive riverine areas, displaced more than 2.1 million people, caused more than 363 deaths, and generated substantial economic losses [43–45]. Subsequent floods have continued to cause fatalities, displacement, infrastructure damage, and humanitarian challenges across the country [24, 46–52]. These recurring impacts indicate that existing flood-management measures remain insufficient.

Despite previous studies addressing rainfall, population growth, urbanization, climate change, and floodplain development, flood mitigation in the Lower Niger has largely emphasized the physical drivers and consequences of flooding [17, 21–24, 34, 35, 38]. A key gap is the limited integration of human behavior, waste-management practices, administrative controls, urban-planning compliance, and enforcement of environmental regulations into explanations of persistent flooding. Existing interventions have also frequently been reactive and localized, limiting their effectiveness and long-term applicability [24]. This gap is increasingly important because Nigeria's population and urbanization continue to increase [53–58].

The novelty of this study lies in integrating hydrological and demographic drivers with floodplain degradation, infrastructure development, waste-management practices, human behavior, administrative controls, and environmental-law enforcement to explain persistent flooding in Delta State riverine communities. Accordingly, this study aimed to examine the major drivers of Niger River and floodplain degradation and their contribution to recurrent flooding in Delta State riverine communities. Specifically, it analyzed rainfall and river-flow characteristics, population and urbanization trends, infrastructure development, waste-management practices, floodplain degradation, and the implementation and enforcement of environmental and urban-planning regulations. Based on these interacting factors, the study proposes integrated measures for mitigating recurrent flooding in Delta State and the wider Lower Niger region.

2. Materials and Methods

2.1. Study Area.

The study focused on floodplain communities along the Lower Niger River in Delta State, southern Nigeria. The broader Niger River Basin extends across nine West African countries: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger, and Nigeria [7–10]. With an estimated active watershed area of approximately 1.5 × 10^6 km², the basin constitutes one of the major hydrological systems in West Africa [59]. Nigeria contains approximately 424,500 km², or 28.3%, of the basin area [3, 7]. The Niger River is approximately 4,200 km long and flows from its source in the Fouta Djallon highlands of Guinea to the Gulf of Guinea through the Niger Delta [2, 3, 7, 8]. The river is generally divided into upper, middle, and lower courses. Its flow regime is strongly influenced by seasonal rainfall, tributary inflows, catchment characteristics, and vegetation cover [7, 9]. In Nigeria, the Benue River forms the principal tributary of the Lower Niger and joins the Niger River at Lokoja. Downstream discharge increases considerably because of tributary contributions and local rainfall. Average annual discharge characteristics at major Nigerian monitoring stations are presented in Table 2 [7, 56]. The river valley becomes progressively broader and lower toward the Niger Delta, where extensive floodplains and distributary channels characterize the landscape [7, 53, 60].

Table 2. Average annual discharge of the Niger River and its major tributaries at selected monitoring stations.

River	Monitoring Station	Altitude (m)	Average Annual Discharge (km^3/year)		Change (%)
			Before 1980	1980s	
Kaduna	Wuya	—	16.5	14.8	−10.3
Benue	Yola	186.1	25.0	13.5	−46.0
Benue	Makurdi	106.4	94.0	74.9	−20.32
Benue	Umaisha	—	108.0	76.7	−29.0
Niger	Kainji Dam	—	36.0	—	—
Niger	Jebba	73	40.7	24.3	−40.3
Niger	Baro	47	61.4	43.3	−29.5
Niger	Lokoja	34	171.5	137.9	−20.0
Niger	Shintaku	—	173.8	139.0	−20.0
Niger	Idah	—	177.0	147.3	−17.0
Niger	Onitsha	270	182.0	—	—
Niger	Niger Delta	0	250.0	—	—

The Niger Delta begins downstream of the Lokoja confluence and covers an estimated floodplain area of approximately 36,000 km² and a total land area of about 70,000 km² [7, 10]. The Niger River divides into more than 30 distributaries before reaching the Gulf of Guinea, creating an extensive network of channels, wetlands, mangroves, and low-lying floodplains [7, 8]. Average annual Niger River discharge at the Niger Delta was approximately 250 km³/year during 1971–2000, while the average for 2010–2018 was approximately 270.5 km³/year, as summarized in Table 3 [3].

Table 3. Average annual discharge of Niger River at the Niger Delta (1971-2000/2010-2018)

Year	Km^3/year	m^3/s
1971-2000	250	7,922.3
2010	288.1	9,130
2011	245.7	7,786
2012	320.3	10,150
2013	224.4	7,111
2014	251.2	7.960
2015	235.3	7,456
2016	286.8	9.088
2017	270.9	8,585
2018	311.6	9.874
2010-2018	270.5	8,572

Delta State is located between approximately 5°00′–6°45′ E and 5°00′–6°30′ N in Nigeria's South-South geopolitical zone. The state covers approximately 18,050 km² and has a coastline of about 160 km along the Bight of Benin. Its landscape is dominated by lowland rainforest, freshwater swamp forest, mangrove ecosystems, and extensive riverine floodplains. The Niger River and major distributaries, including the Forcados and Escravos Rivers, traverse the state before discharging into the Gulf of Guinea. The selected study locations included floodplain areas within Ndokwa East, Ndokwa West, Isoko North, Isoko South, Ughelli North, and Warri North Local Government Areas (LGAs). Their locations within the Lower Niger floodplain are shown in Figure 1 [62].

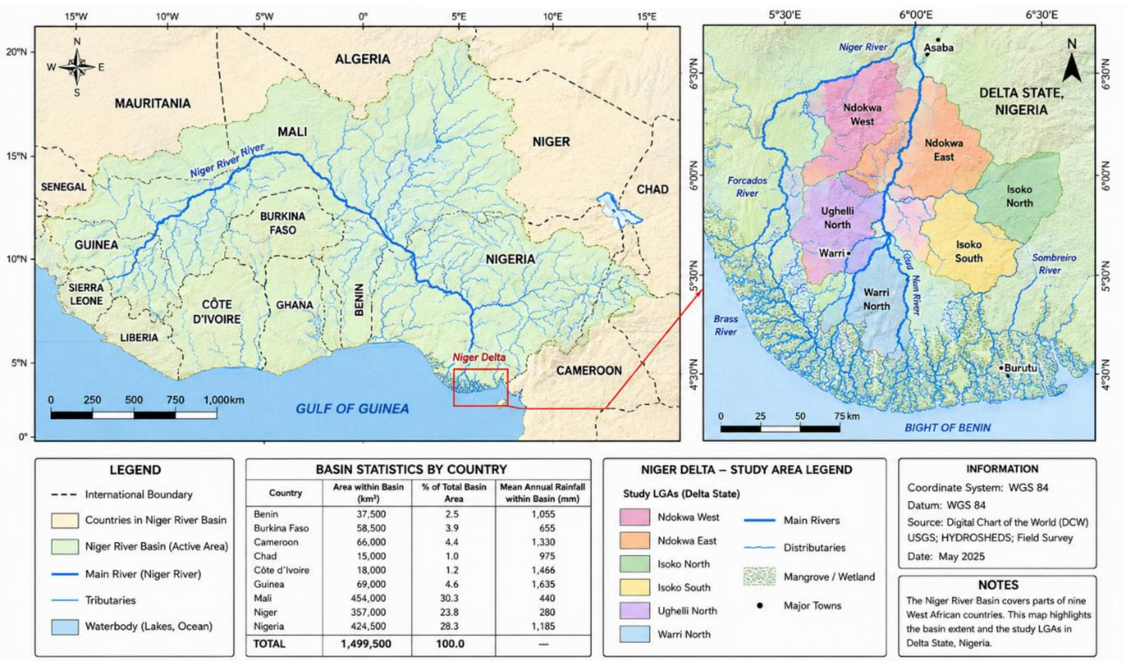

Figure 2. Niger Delta showing the Lower Niger floodplains, Niger River distributaries, and study locations.

2.2. Data Sources and Collection.

The study integrated secondary data with long-term field observations to evaluate the factors contributing to river-system degradation and flooding in Delta State. Secondary data were obtained from relevant local, regional, national, and international government agencies, departments, parastatals, private institutions, and published research. The datasets covered Nigeria's population and urbanization trends from 1950 to 2023, Niger River Basin rainfall, annual precipitation in Nigeria from 2008 to 2016, road infrastructure development from 1950 to 2023, waste-management practices during 2007–2010 and 2015, and Niger Delta Development Commission (NDDC) projects in Delta State.

2.3. Field Observation and Channel Assessment.

Field observations were conducted across selected locations in Ndokwa East, Ndokwa West, Isoko North, Isoko South, Ughelli North, and Warri North LGAs between 1996 and 2026. Observations focused on urban expansion, commercial and residential development, infrastructure encroachment, selected Niger River distributaries, floodplain modification, and waste-management practices. Channel conditions were assessed through periodic measurements and observations of distributary width and depth. Changes in channel dimensions were used to evaluate the extent of channel degradation and identify evidence of aggradation. Field observations also documented waste deposition, accumulation, and sedimentation within drainage channels, river channels, and floodplains. These observations were compared with available waste-management records for Delta State.

2.4. Data Analysis.

The collected information was analyzed descriptively to identify temporal and spatial relationships among rainfall, river discharge, population growth, urbanization, infrastructure development, waste management, channel degradation, and flooding. Population and urbanization trends were compared with changes in infrastructure development and floodplain occupation, while rainfall and discharge records were examined to characterize the hydrological conditions influencing flooding. Field observations of channel narrowing, sediment accumulation, and waste obstruction were compared with available secondary data to assess their potential contribution to reduced flow capacity and flood occurrence. The integrated analysis was used to identify the principal natural, anthropogenic, and administrative factors associated with recurrent flooding in Delta State floodplain communities and to evaluate their implications for flood-management strategies.

3. Results and Discussion

3.1. Floodplain Characteristics and Flood Vulnerability.

The Lower Niger River system consists of an extensive network of tributaries, distributaries, streams, creeks, wadis, lakes, lagoons, marshes, and swamps. These floodplains function as natural storage areas for excess water during the wet season and therefore contribute to flood regulation. Three principal floodplain zones were identified: primary, secondary, and higher floodplains. The primary floodplain maintains direct contact with river channels throughout the year and includes creeks, swamps, and wadi outlets. The secondary floodplain occurs at a higher elevation and contains marshes, lakes, creeks, and seasonally inundated lowlands. At Aboh, for example, the secondary floodplain begins approximately 4 m above the primary floodplain and extends to about 13 m.

Many Lower Niger communities in Delta State are located only 7–20 m above the adjoining floodplains, while several riverine settlements are approximately 20–40 m or less above sea level. Aboh, for example, is approximately 24 m above sea level. As illustrated in Figure 2, this predominantly fluvial landscape makes Delta State and the wider Niger Delta particularly susceptible to both fluvial and pluvial flooding during periods of intense rainfall and elevated river discharge. This vulnerability is consistent with previous observations that approximately 40% of the global population lives within 100 km of a coastline and that more than 600 million people inhabit coastal areas less than 10 m above sea level [32, 64–67].

3.2. Population Growth, Urbanization, and Floodplain Degradation.

Prior to the 1980s, floodplains were estimated to occupy approximately 60–90% of the area surrounding many riverine communities in Delta State. However, continued population growth, urbanization, and infrastructure development have progressively converted these natural flood-storage areas into built environments. The demographic trends summarized in Figure 3 show substantial increases in Nigeria's total population, urban population, population density, and level of urbanization between 1950 and 2023. The national population increased from approximately 37.19 million in 1950 to 95.21 million in 1990 and 223.80 million in 2023, while the urban population increased from about 3.34 million to 122.55 million over the same period. The accompanying increase in population density and urbanization demonstrates the growing pressure on available land, particularly in low-lying and riverine areas.

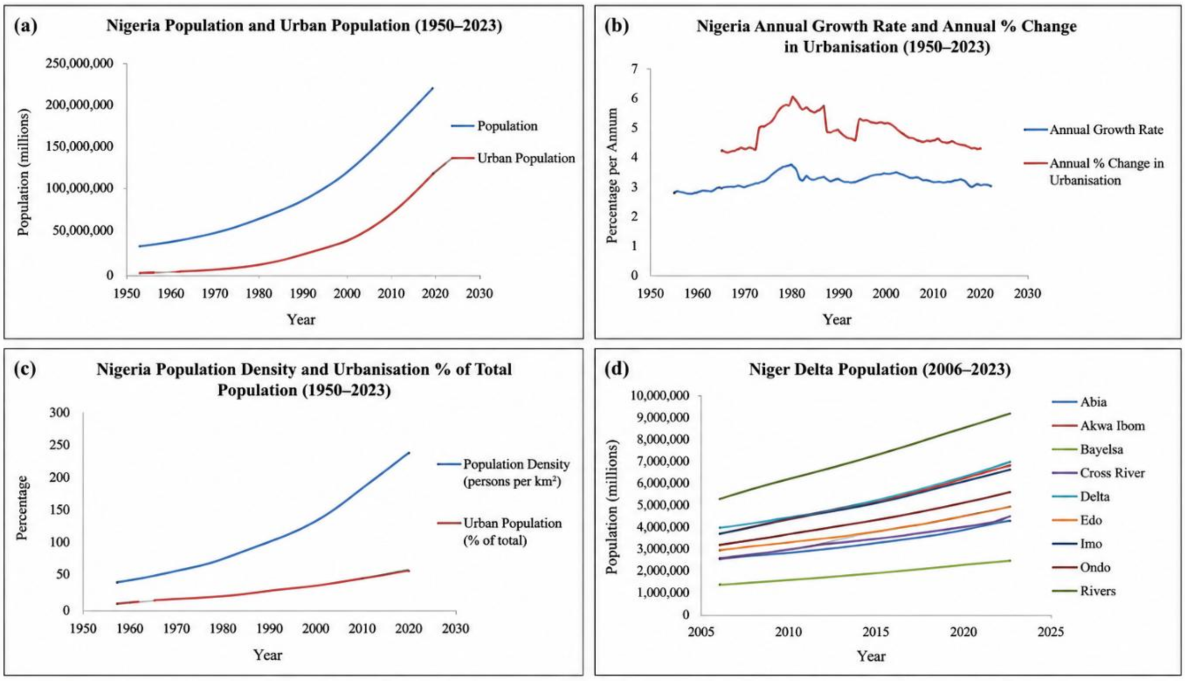

Figure 3. Demographic and urbanization trends in Nigeria and the Niger Delta (1950–2023).

A similar pattern was observed in the Niger Delta, where population growth intensified pressure on floodplains and other hydrologically sensitive areas. As also shown in Figure 3, the Niger Delta population increased substantially between 2006 and 2023. These demographic trends are important because population growth, population ageing, urbanization, and internal migration strongly influence the spatial expansion of human settlements and infrastructure demand [33]. In the Lower Niger, the limited availability of elevated land has encouraged the expansion of settlements into river corridors, wetlands, and floodplains.

The relationship between demographic pressure and floodplain degradation is further demonstrated in Figure 4, which provides field evidence of infrastructure development within the Niger River floodplain in Asaba. Similar occupation of riverbanks and floodplain areas was observed at Oko-Asaba, Ogbaru, Onitsha, Aboh, Burutu, Effurun, Osubi, Patani, Ughelli, and Warri. Residential, commercial, transportation, industrial, and religious developments in these areas reduce natural flood-storage capacity and increase the extent of impervious surfaces. Consequently, runoff is generated more rapidly and conveyed toward already constrained river and drainage systems. These observations support [41], who emphasized the importance of adapting infrastructure planning to increasing urbanization and rainfall intensity.

Figure 4. Niger River floodplain under degradation for provision of infrastructure in Asaba Delta State, Nigeria.

3.3. Infrastructure Development and Hydrological Modification.

Infrastructure development has progressively altered the hydrological characteristics of the Lower Niger floodplain by increasing impervious surface coverage, reducing infiltration, and modifying natural flow pathways. Approximately 10 km of the A232 road between Abraka Road in Asaba and the Niger Bridge occupies or traverses the Lower Niger floodplain. Other federal roads, including F103, F223, F227, and F228, also cross substantial sections of the Lower Niger and its associated floodplains. In addition, petroleum infrastructure was estimated to occupy more than 1,000 km^2 of floodplain in Delta State and over 5,000 km^2 across the Niger Delta. Such development can restrict natural drainage and accelerate runoff, particularly during periods of intense rainfall [32, 38].

The long-term expansion of Nigeria's road infrastructure is summarized in Table 4. The available records indicate substantial growth in the national road network between 1951 and 2010–2014, together with an increasing extent of paved surfaces. By 2010–2014, the reported road network had reached approximately 200,000 km, comprising federal, state, and local government roads. Although differences in historical road classifications limit direct comparison among all periods, the overall trend indicates increasing infrastructure development. From a hydrological perspective, expansion of paved surfaces can reduce infiltration and increase the volume and rate of surface runoff reaching drainage channels and receiving rivers [74–76].

Table 4. Structure, ownership, and extent of the road network in Nigeria (1951–2014).

Period/Year	Road Ownership/Category	Paved (km)	Unpaved (km)	Other Roads (km)	Total (km)	Share (%)
2010–2014	Federal	30,342.3	5,840.5	—	36,182.8	18
	State	28,560.0	5,440.0	—	34,000.0	17
	Local government	—	—	129,817.2	129,817.2	65
	Total	**58,902.3**	**11,280.5**	**129,817.2***	**200,000.0**	**100**
	Surface share (%)	**29**	**6**	**65**	**100**	—
2007–2009	Federal	30,423.5	5,759.5	—	36,183.0	19
	State	29,559.6	5,216.4	—	34,776.0	18
	Local government	—	—	122,241.0	122,241.0	63
	Total	**59,983.1**	**10,975.9**	**122,241.0**	**193,200.0**	**100**
	Surface share (%)	**31**	**6**	**63**	**100**	—
2005–2006	Federal	28,453.5	5,887.7	—	34,341.2	18
	State	27,260.5	5,583.5	—	32,844.0	17
	Local government	—	—	126,358.8	126,358.8	65
	Total	**55,714.0**	**11,471.2**	**126,358.8***	**193,200.0***	**100**
	Surface share (%)	**29**	**6**	**65**	**100**	—
2004	Federal	26,500	5,600	—	32,100	17
	State	10,400	20,100	—	30,500	16
	Local government—urban	—	—	21,900	21,900	11
	Local government—main rural	—	—	72,800	72,800	37
	Local government—village access	—	—	35,900	35,900	19
	Total	**36,900**	**25,700**	**130,600**	**193,200**	**100**
	Surface share (%)	**19**	**13**	**68**	**100**	—
1990	All roads	55,000	53,000	—	**108,000**	—
1960	Reported national network	3,830.4	5,035.2	—	**8,865.6**	—
	Regional	3,019.2	4,368.0	—	7,387.2	41
	States/local government	1,156.8	56,323.2	—	57,480.0	—
	Reported total	**8,006.4**	**65,726.4**	—	**73,732.8**	**100**
	Surface share (%)	**11**	**89**	—	**100**	—
1951	All roads	**1,782**	**42,632**	—	**44,414**	—

Table 5 provides a more specific assessment of federal road development in Delta State. Total federal road length increased from 732.5 km in 2005–2006 to 1,220.5 km in 2007–2019, with paved roads accounting for a substantial proportion of this expansion. The increase is particularly relevant to flood management because many road corridors occur within low-lying and hydrologically sensitive areas. Where adequate drainage structures are absent or insufficient, roads and associated embankments may function as barriers to natural water movement and contribute to localized water accumulation [25–31, 74–76].

Table 5. Federal road network in Delta State, Niger Delta, by surface type (2005–2019).

Period	Paved Roads (km)	Surface-Dressed Roads (km)	Gravel/Earth Roads (km)	Total Road Length (km)	Reported Area (km²)
2005–2006	657.5	37.0	38.0	732.5	5,069.85
2007–2019	1,048.5	10.0	162.0	1,220.5	7,727.05

The physical vulnerability of the region is further demonstrated in Table 6, which compares land and water areas in Delta State, the Niger Delta, and other Niger and Benue River states. Water accounts for approximately 3.33% of the total area of Delta State and 9.90% of the Niger Delta, highlighting the extensive presence of rivers, creeks, wetlands, and other aquatic environments. The relatively large proportion of water area in the Niger Delta reflects its strongly fluvial character and emphasizes the importance of maintaining natural drainage corridors and flood-storage areas [25–31].

Table 6. Land and water areas of Delta State, the Niger Delta, and other Niger and Benue River states.

Region	Total Area (km²)	Land Area (km²)	Water Area (km²)	Share of Nigeria's Total Area (%)	Land Area (%)	Water Area (%)
Delta State	17,698	17,108	590	1.92	96.67	3.33
Niger Delta	111,043	100,049	10,994	12.02	90.10	9.90
Other Niger and Benue River states	394,227	380,598	13,629	42.68	96.54	3.46
Nigeria	**923,769**	**909,890**	**13,879**	**100.00**	**98.50**	**1.50**

Infrastructure development associated with Niger Delta Development Commission (NDDC) projects has also contributed to land-use modification. As shown in Table 7, 9,387 NDDC projects were reported across the Niger Delta, including roads and bridges, buildings, electricity infrastructure, water-supply facilities, jetties, reclamation, and shore-protection projects [77]. Roads and bridges constituted the largest project category, with 3,869 projects, followed by 1,890 building projects. These developments provide socioeconomic benefits but may increase impervious surface coverage and interfere with natural drainage where they are located within floodplains. The combined effects of population growth, urbanization, and infrastructure development therefore increase the potential for flow restriction and floodwater spreading. This interpretation is consistent with [32, 38], who associated floodplain development with increased flood vulnerability.

Table 7. Distribution of Niger Delta Development Commission (NDDC) projects across the Niger Delta and Delta State.

State	n	Project Category	n	Delta State LGA	n	Delta State LGA	n
Abia	702	Buildings	1,890	Aniocha North	43	Ndokwa West	21
Akwa Ibom	1,198	Canalization	65	Aniocha South	8	Okpe	47
Bayelsa	865	Dredging	17	Bomadi	172	Oshimili North	24
Cross River	427	Electricity	1,754	Burutu	188	Oshimili South	40
Delta	1,652	Equipment	64	Ethiope East	54	Patani	66
Edo	742	Furnishing	28	Ethiope West	48	Sapele	37
Imo	740	ICT	11	Ika North East	21	Udu	68
Ondo	826	Jetties	156	Ika South	10	Ughelli North	104
Rivers	2,235	Reclamation/shore protection	241	Isoko North	110	Ughelli South	61
Total	**9,387**	Roads/bridges	3,869	Isoko South	116	Ukwani	12
		Water supply	1,288	Ndokwa East	25	Uvwie	134
				Warri North	66	Warri South	145
				Warri South-West	7		
		Reported total	**9,387***	**Delta State LGA total**	**1,627**		

3.4. Waste Management, Channel Degradation, and Flooding.

Population growth and urbanization have increased waste generation and intensified waste-management challenges across the Niger Delta. Inadequate collection and disposal practices allow solid waste to accumulate in drainage channels, river valleys, and floodplains. During rainfall events, surface runoff can transport these materials into river systems, where waste accumulation and sedimentation may obstruct flow pathways, reduce channel capacity, and increase flood susceptibility. Table 8 presents waste-management practices across the nine Niger Delta states from 2007 to 2010 and demonstrates both spatial and temporal variability among the different disposal methods. Practices classified in this study as unethical waste management remained consistently dominant, accounting for 79.19% in 2007, 74.86% in 2008, 76.44% in 2009, and 84.75% in 2010. Although the proportion declined slightly between 2007 and 2008, it subsequently increased and reached its highest level in 2010. Considerable differences were also observed among individual states and disposal categories, indicating that waste-management conditions were not uniform throughout the Niger Delta. The persistence of high proportions across the four-year period suggests that inappropriate disposal represented a continuing regional environmental-management challenge rather than an isolated annual occurrence [78].

Table 8. Waste Management in Niger Delta (2007 – 2010).

Year	**2007**						**2008**					
State	A	B	C	D	E	F	A	B	C	D	E	F
Abia	1.4	1.3	10.8	51.6	29.0	5.9	0.2	3.0	4.7	28.9	34.4	28.8
Akwa Ib.	1.3	4.0	1.1	88.7	3.4	1.5	2.1	0.5	3.8	86.1	6.9	0.7
Bayelsa	4.2	0.0	2.0	44.9	32.1	16.7	0.0	1.2	2.7	12.9	12.2	71.0
Cross R.	14.9	0.2	2.1	37.4	21.7	23.7	2.5	0.2	8.1	29.8	40.5	18.8
Delta	2.4	4.0	1.4	10.2	65.1	16.9	0.7	7.9	5.0	41.1	39.4	6.0
Edo	1.1	3.6	0.0	31.5	58.2	5.7	0.0	3.4	0.0	17.9	77.8	0.8
Imo	4.4	0.6	0.7	54.3	31.3	8.7	1.2	7.0	2.0	56.0	26.2	19.9
Ondo	0.0	1.7	0.6	16.2	65.0	16.6	0.5	0.0	0.0	28.3	48.0	18.0
Rivers	4.1	2.2	7.1	28.8	43.3	14.5	6.7	3.2	2.0	32.6	55.5	0.0
Mean	3.75	1.95	2.87	40.4	38.79	12.24	1.54	2.93	3.14	37.06	37.80	18.22
% of unethical waste mgt						**79.19**	**% of unethical waste mgt**					**74.86**

Year	**2009**						**2010**						
State	**A**	**B**	**C**	**D**	**E**	**F**	**A**	**B**	**C**	**D**	**E**	**F**	**N**
Abia	2.0	3.9	0.6	32.3	53.6	7.6	5.2	2.5	7.3	57.7	19.7	1.5	6.1
Akwa I.	0.0	0.0	5.0	80.5	14.6	0.0	0.4	0.4	1.3	76.3	21.0	0.2	0.2
Bayelsa	0.4	0.0	1.1	16.5	20.6	61.3	2.9	0.4	4.4	41.0	33.0	13.2	5.2
Cross R.	5.9	0.0	10.0	61.3	16.6	6.1	1.9	0.9	11.0	45.0	35.6	0.7	4.9
Delta	0.2	2.3	0.6	38.1	52.5	6.3	5.5	7.0	6.7	37.6	20.6	9.7	12.9
Edo	11.6	2.5	0.3	26.9	51.7	7.0	2.0	4.3	1.0	38.7	42.5	2.0	9.4
Imo	1.3	0.6	0.8	59.4	11.7	26.2	4.0	0.0	0.5	79.3	15.0	0.7	27.0
Ondo	0.2	0.2	2.5	33.3	49.0	14.8	3.7	1.5	1.1	30.2	30.9	5.7	27.0
Rivers	0.2	6.6	6.3	21.8	47.6	17.5	0.3	4.0	1.1	14.9	34.0	22.3	23.6
Mean	2.42	1.79	30.02	41.12	35.32	16.31	2.88	2.33	3.82	46.74	28.03	6.22	9.98
% of unethical waste mgt						**76.44**	**% of unethical waste mgt**						**84.75**

Table 9 broadens the analysis by presenting waste-management practices in other states associated with the Niger and Benue River systems. The data indicate that inappropriate waste disposal was not restricted to the Niger Delta but occurred across a wider geographical area connected by major rivers and drainage networks. This finding has important downstream implications because waste generated or deposited upstream can be redistributed through surface runoff and river transport. Consequently, inadequate waste management in upstream and middle-basin communities may contribute to sediment and solid-waste accumulation farther downstream, including within the Lower Niger. The results therefore demonstrate that waste-related river degradation should be considered a basin-scale management issue rather than solely a local problem in Delta State [78]

Table 9. Waste management in other states along the Niger and Benue Rivers.

Year	2007						2008					
State	A	B	C	D	E	F	A	B	C	D	E	F
Adamawa	0.1	0.7	8.2	34.2	51.1	5.7	0.2	0.5	1.4	28.3	69.2	0.4
Anambra	2.8	3.4	0.0	47.8	39.7	6.2	5.4	0.7	1.4	28.0	43.9	20.6
Benue	0.1	0.0	0.0	32.9	66.8	0.2	0.9	4.5	0.2	48.1	46.0	0.3
Gombe	0.0	5.8	0.0	32.8	61.4	0.0	6.0	0.0	0.0	43.6	49.9	0.5
Kebbi	0.0	0.4	0.9	94.0	4.1	0.6	0.0	0.0	0.0	71.5	27.5	1.1
Kogi	0.0	0.1	0.3	10.2	82.9	6.6	0.0	0.0	0.0	27.8	70.0	2.2
Kwara	2.3	0.0	2.7	31.9	44.4	18.8	0.0	0.0	2.1	28.2	69.7	0.0
Nasarawa	0.1	0.0	0.0	14.6	60.3	25.0	1.4	0.0	0.2	36.8	55.2	6.5
Niger	0.0	0.0	0.0	12.9	85.7	1.4	0.2	0.2	1.1	13.1	84.4	1.1
Plateau	0.6	0.2	0.1	33.4	62.1	3.7	0.7	0.0	0.5	31.4	66.8	0.5
Taraba	0.0	0.7	0.0	42.8	52.9	3.6	0.0	0.6	0.0	60.8	38.6	0.0
FCT	3.3	10.7	1.1	12.2	68.8	3.9	3.2	6.4	0.7	18.3	65.5	5.9
Mean	0.78	1.83	1.10	33.30	56.68	6.30	1.5	1.07	0.63	36.32	57.23	3.25
% of unethical waste mgt						**89.96**	**% of unethical waste mgt**					**90.55**

Year	2009						2010						
State	A	B	C	D	E	F	A	B	C	D	E	F	N
Adamawa	0.9	0.0	0.4	29.7	66.7	2.3	4.1	1.6	1.8	34.2	48.3	1.8	8.2
Anambra	0.9	0.7	1.7	32.7	53.1	10.9	5.8	5.8	3.4	29.6	35.4	5.8	14.0
Benue	0.0	19.5	4.5	48.2	27.8	0.0	0.2	0.9	0,2	31.0	47.8	0.2	19.6
Gombe	0.0	0.2	7.9	43.9	45.4	2.6	0.3	1.4	0.0	18.6	78.8	0.8	0.0
Kebbi	0.0	0.0	2.2	78.4	18.9	0.4	2.4	1.2	1.4	57.9	25.7	1.4	9.9
Kogi	0.2	0.2	0.2	13.6	78.2	7.5	0.9	6.5	2.2	1.5	70.3	8.7	10.0
Kwara	1.3	0.0	3.6	21.9	68.2	4.9	8.8	0.9	0.5	21.4	56.5	0.7	11.2
Nasarawa	0.0	0.0	10.3	30.6	57.3	1.8	0.4	9.6	0.2	30.7	38.8	0.6	19.8
Niger	1.8	4.6	0.0	20.1	69.1	4.3	3.1	0.5	1.0	27.2	59.6	7.9	0.7
Plateau	0.0	0.0	0.0	31.7	55.1	13.2	0.0	0.6	1.0	21.3	41.7	0.6	29.5
Taraba	0.0	0.4	0.0	34.8	64.4	0.4	0.3	2.8	0.0	21.3	42.1	2.3	31.3
FCT	3.0	7.7	0.5	7.9	66.2	14.8	2.5	2.5	5.8	25.8	52.9	3.1	7.3
Mean	0.67	2.77	2.77	32.78	55.80	5.20	2.4	2.86	1.46	27.15	49.83	2.84	13.46
% of unethical waste mgt						**88.58**	**% of unethical waste mgt**						**90.44**

Table 10 provides a later assessment of waste-management practices across Nigeria's geopolitical zones in 2015. The results show that inappropriate disposal methods remained substantial several years after the 2007–2010 assessment, indicating the persistence of structural limitations in waste collection and disposal. Differences among geopolitical zones further suggest that the effectiveness of waste-management systems varied geographically. For the Lower Niger and Niger Delta, continued inappropriate disposal is particularly concerning because dense drainage networks and high seasonal runoff provide pathways through which improperly discarded waste can enter streams, tributaries, distributaries, and floodplains. The 2015 data therefore reinforce the need for improved waste collection, controlled disposal facilities, public participation, and stronger enforcement of environmental regulations [78].

Table 10. Nigeria waste management statistics (2015).

Refuse Disposal (%)	North Central	North East	South East	South-South	South West	Rural
A	3.6	1.2	10.1	8.7	28.8	1.8
B	2.9	0	1.5	5.2	7.5	0.5
C	22	1.1	5.5	3	1	0.8
D	7.9	9	27.6	27.6	12.6	27
E	49.4	46.7	21.3	27.2	17.3	30.8
F	3.1	0.1	2	2.4	1.8	1.6
N	30.9	41.9	32	25.8	31.1	37.5

A; refuse bins managed by government agency, B; refuse managed by private agency, C; government bin or shred, D; disposal within compound, E; unauthorized disposal, F; other types, N is none.

Waste accumulation has implications beyond water pollution. Deposited material and associated sediment can form physical barriers within drainage and river channels, reducing conveyance capacity and promoting the lateral spreading of floodwater into surrounding lowlands. This process becomes particularly important during intense rainfall events [78]. Flooding may be broadly classified as fluvial, pluvial, or coastal, while flash floods represent a rapidly developing form of pluvial flooding associated with intense rainfall over relatively small areas [79]. The interaction between rainfall, channel degradation, waste accumulation, urbanization, and infrastructure development provides a more comprehensive explanation for recurrent flooding in Delta State than rainfall alone. The Lower Niger's naturally low-lying terrain already creates high hydrological susceptibility, while anthropogenic modification reduces the capacity of channels and floodplains to accommodate excess water. Recurrent flooding in Aboh, Abuator Umu-Iweli, Ashaka, Beneku, Okpai, Patani, and other riverine communities during major flood events, including those of 2012, 2016, 2018, and 2022, therefore reflects the combined effects of natural hydrological conditions and human-induced floodplain degradation.

3.5. Implications for Flood Mitigation.

The findings indicate that effective flood management in Delta State requires a shift from predominantly reactive measures toward integrated and preventive approaches. Infrastructure development is necessary to accommodate population growth and socioeconomic development; however, construction within strategic river corridors and flood-storage areas should be carefully regulated. Stronger implementation of environmental and urban-planning regulations could reduce uncontrolled floodplain development and inappropriate waste disposal while protecting natural flow pathways. Nature-based measures should complement regulatory approaches. Wetland restoration, vegetative buffers, retention areas, and restoration of degraded tributaries and distributaries can increase water-storage and infiltration capacity. This approach is consistent with [32], which emphasized the potential of natural and artificial wetlands for flood mitigation. Similarly, [80] reported that approximately 1.3 million trees could retain up to 7×10^9 m^3 of rainwater annually, illustrating the potential contribution of vegetation to stormwater management. Accordingly, flood mitigation should integrate river-channel restoration, desilting, floodplain protection, sustainable waste management, appropriate infrastructure planning, vegetative buffers, administrative controls, and stronger enforcement of existing environmental regulations. Such an integrated approach would address both the hydrological and anthropogenic drivers of recurrent flooding in Delta State and the wider Lower Niger region.

4. Conclusions

This study demonstrated that recurrent flooding in Delta State riverine communities results from the interaction of natural hydrological conditions and increasing anthropogenic pressures. The Lower Niger is characterized by extensive low-lying floodplains, high seasonal rainfall, and substantial river discharge, with local rainfall contributing considerably to downstream flow. These natural conditions make Delta State inherently vulnerable to fluvial and pluvial flooding. However, rapid population growth, urbanization, infrastructure development, increasing impervious surfaces, inappropriate waste disposal, and degradation of river channels and floodplains have further intensified flood risks. Poor implementation and enforcement of environmental and urban-planning regulations have contributed to channel obstruction, sedimentation, reduced flood-storage capacity, and the recurrent flooding observed in 2012, 2016, 2018, and 2022. Effective flood mitigation therefore requires a shift from reactive interventions toward integrated and proactive management. Priority measures should include stronger enforcement of environmental and urban-planning regulations, sustainable waste management, restoration and desilting of degraded tributaries and distributaries, protection of strategic floodplains, and restriction of inappropriate development within natural drainage corridors. Nature-based solutions, including wetlands, retention areas, and vegetative buffers, should complement engineered flood-control measures. Integrating hydrological management, infrastructure planning, environmental regulation, and responsible human behavior is essential for improving the long-term flood resilience of Delta State communities.

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References

[1] Ndikom, O.B.; Nwokedi, T.C.; Buhari, S.O.; Nathaniel, O.C.; Nwosu, S.O. (2022). Economic viability of major river ports in Nigeria in the movement of goods and passengers to the hinterland. *Advances in Transportation and Logistics*, *2*, 1–10.

[2] Guero, A. (2014). Niger River Basin Authority: Legal and Institutional Frameworks, Ongoing Projects and Initiatives and Cooperation; First Coordination Meeting of the Sahel Project "Sustainable Management of Water Resources in the Sahel Region": Vienna, Austria.

[3] Medinilla, A. (2017). Understanding the Niger Basin Authority (NBA/ABN): Reconciling Upstream and Downstream Interests on the Niger River; European Centre for Development Policy Management, pp. 1–27.

[4] Ogunjo, S.; Olusola, A.; Olusegun, C. (2024). Predicting river discharge in the Niger River Basin: a deep learning approach. *Applied Sciences*, *14*, 1–18. https://doi.org/10.3390/app14010012.

[5] Dunia, J.E.; Okla, E.S. (2025). Nupe migrants along the Niger River: interrogating shifting occupation in Agenebode since 1945. *Edo Journal of History and International Studies*, *1*, 172–190.

[6] Andersen, I.; Dione, O.; Jarosewich-Holder, M.; Olivry, J.-C. (2005). The Niger River Basin: A Vision for Sustainable Development; The World Bank: Washington, DC, USA. https://doi.org/10.1596/978-0-8213-6203-7.

[7] Mabogunje, A.L. (2019). Niger River; Encyclopaedia Britannica, Inc.: Chicago, IL, USA.

[8] Amadou, A.; Djibo, A.G.; Seidou, O.; Sanda, I.S.; Sittichok, K. (2015). Changes to flow regime on the Niger River at Koulikoro under a changing climate. *Hydrological Sciences Journal*, *60*, 1709–1723. https://doi.org/10.1080/02626667.2014.916407.

[9] Olubomehin, O.O. (2015). Development of the national trunk roads in Nigeria and the socio-economic impact, 1960–2013. *Lagos Historical Review*, *15*, 1–16. https://doi.org/10.4314/1hr.v15i1.1.
[10] Ali, A.D. (2013). The colonial economy in the Lower Niger region. *Arabian Journal of Business and Management Review (OMAN Chapter)*, *2*, 47–54.
[11] Ali, A.D. (2012). Trade and Transport in the Lower Niger 1830–2011; Adenuga Concepts: Lagos, Nigeria.
[12] Akubor, E.O. (2014). Trade and commerce along the Niger: the Igala and the development of Egga (river bank) trade/commerce in southwestern bank of the River Niger. *Developing Country Studies*, *4*, 1–10.
[13] Ogunbodede, E.F. (2008). Urban road transportation in Nigeria from 1960 to 2006: problems, prospects and challenges. *Ethiopian Journal of Environmental Studies and Management*, *1*, 7–18.
[14] Pillah, T.P. (2023). Population and housing census in Nigeria. *Journal of Public Administration, Policy and Governance Research*, *1*, 1–12.
[15] Salihu, H.A. (2025). The role of riverine trade in shaping intergroup relations in the Niger-Benue confluence region up to 1900. *Uzu Journal*, *10*, 66–82.
[16] Duyile, W.A. (2019). Contexting and historicizing European and riverine nationalities patterns of seamanship and water-borne warfare in prior colonial Nigeria. *London Journal of Research in Humanities and Social Sciences*, *19*, 1–12.
[17] Chikanele, A. (2016). Population growth and development in Nigeria: an overview. *IIARD International Journal of Economics and Business Management*, *2*, 38–53.
[18] Nwosu, C.; Dike, A.O.; Okwara, K.K. (2014). The effects of population growth on economic growth in Nigeria. *The International Journal of Engineering and Science*, *3*, 7–18.
[19] Idowu, O.O. (2013). Challenges of urbanization and urban growth in Nigeria. *American Journal of Sustainable Cities and Society*, *1*, 79–95.
[20] The Infrastructure Policy Commission (2024). Bridging the Housing and Urban Development Divide; White Paper of the Nigerian Economic Summit Group: Lagos, Nigeria.
[21] Ogunjimi, J.A.; Oladipupo, D.O. (2018). Dynamics of demographic structure and economic growth in Nigeria. Munich Personal RePEc Archive, pp. 1–17.
[22] Nigeria's Housing Construction and Housing Rental Activities Cost Benchmarking and Impact on the Economy; Center for Affordable Housing Finance in Africa: Johannesburg, South Africa. accessed on 14 November 2023) Available online: http://housingfinanceafrica.org/documents/using-cahfs-housing-cost-benchmarking-methodology-to-analyse-housing-costs-in-fifteen-african-countries/.
[23] Ojo, O.O.; Ipingbemi, O. (2025). Motorisation and road conditions across land uses in Ibadan, Nigeria. *Iconic Research and Engineering Journals*, *8*, 175–189.
[24] Nkwunonwo, U.C. (2016). A review of flooding and flood risk management in Nigeria. *Global Journal of Human-Social Science*, *16*, 24–42.
[25] Kale, Y. (2017). Annual Abstracts of Statistics (2016), Vol. 1; National Bureau of Statistics: Abuja, Nigeria.
[26] NBS (2014). Demographic Statistics Bulletin 2013; National Bureau of Statistics: Abuja, Nigeria.
[27] Kale, Y. (2017). Annual Abstracts of Statistics (2016), Vol. 1; National Bureau of Statistics: Abuja, Nigeria.
[28] Kale, Y. (2016). Demographic Statistics Bulletin 2015; National Bureau of Statistics: Abuja, Nigeria.
[29] Kale, Y. (2017). Annual Abstracts of Statistics, Vol. 1, 2016; National Bureau of Statistics: Abuja, Nigeria.
[30] Kale, Y. (2013). Annual Abstracts of Statistics 2011; National Bureau of Statistics: Abuja, Nigeria..

[31] Kale, Y. (2014). Annual Abstracts of Statistics 2012; National Bureau of Statistics: Abuja, Nigeria.
[32] Molnar-Tanaka, K.; Surminski, S. (2024). Nature-Based Solutions for Flood Management in Asia and the Pacific; OECD Development Centre Working Papers No. 351; OECD Development Centre: Paris, France.
[33] United Nations (2024). World Population Prospects 2024: Summary of Results; UN DESA/POP/2024/TR/NO. 9; United Nations: New York, NY, USA.
[34] Agbonkhese, O.; Agbonkhese, E.G.; Aka, E.O.; Joe-Abaya, J.; Ocholi, M.; Adekunle, A. (2014). Flood menace in Nigeria: impacts, remedial and management strategies. *Journal of Civil and Environmental Research*, *6*, 32–40.
[35] Tacoli, C.; McGranahan, G.; Satterthwaite, D. (2014). World Migration Report 2015: Urbanization, Rural-Urban Migration and Urban Poverty; International Organization for Migration: London, UK.
[36] Number of Cars in Operation per 1,000 People in Nigeria from 2013 to 2028. (accessed on 14 November 2023) Available online: https://www.statista.com/forecasts/1152101/carparc-forecast-in-nigeria.
[37] Odey, S.A.; Akpenke, S.A. (2020). Population and development in Nigeria: contemporary issues and prospects. *Global Journal of Politics and Law Research*, *8*, 32–49.
[38] Coleman, M.; de Vries, A.-J.; Roberts, C.; Domeisen, D.I.V. (2026). Floods in the European Union and the Middle East and North Africa region: socio-economic impacts, characteristics, and public perception. *EGUsphere*, preprint. https://doi.org/10.5194/egusphere-2026-1827.
[39] River Systems and Causes of Flooding; Geology 204, Tulane University: New Orleans, LA, USA. (accessed on 23 October 2011) Available online: www.tulane.edu/sanelson/geo/204/subsidence.pdf.
[40] Flooding in Nigeria: Causes, Effects and Solution. (accessed on 23 October 2011) Available online: https://nairaproject.com/projects/4120.html.
[41] Bento, A.M.; Cordier, F.; Dewals, B.; El Kadi Abderrezzak, K.; Ferradosa, T.; Gisonni, C.; López-Jiménez, P.A.; Molinari, D.; Pummer, E.; Rowiński, P.M.; Schröter, K.; Stamou, A.I. (2024). Lessons learnt from recent flood disasters in Europe: indicative cases; 8th IAHR Europe Congress: Lisbon, Portugal.
[42] The International Bank for Reconstruction and Development (2010). Climate Risks and Adaptation in Asian Coastal Megacities: A Synthesis Report; The International Bank for Reconstruction and Development/The World Bank: Washington, DC, USA.
[43] Agency: Nigeria floods kill 363 people, displace 2.1 m. (accessed on 26 November 2012) Available online: https://www.jpost.com/breaking-news/agency-nigeria-floods-kill-363-people-displace-21-m/article-290573.
[44] Urbanisation and Urban Expansion in Nigeria; Urbanisation Research Nigeria (URN) Research Report. (accessed on 14 November 2023) Available online: http://urn.icfwebservices.com/Media/Default/Research%20Reports/URN%20Theme%20A%20Urbanisation%20Report%20FINAL.pdf.
[45] 2012 Flood Disaster Cost Nigeria N2.6tn—NEMA. (accessed on 14 November 2023) Available online: https://www.scirp.org/reference/referencespapers?referenceid=3594283.
[46] Flooding in northeastern Nigeria has left 30 people dead and over a million displaced. (accessed on 9 September 2012) Available online: https://apnews.com/article/flooding-northern-nigeria-borno-dam-collapse-60ed5b7bddfc4a5b65c0a0573d735d2b.
[47] Nigeria floods test government disaster plans. (accessed on 27 May 2015) Available online: https://www.theguardian.com/global-development/2013/aug/28/nigeria-floods-disaster.
[48] Nigeria floods kill dozens, wash hippos and crocodiles into homes. (accessed on 27 May 2015) Available online: https://www.cnn.com/2012/10/05/world/africa/nigeria-floods.

[49] Nigeria flooding called 'natural disaster'. (accessed on 27 May 2015) Available online: https://www.aljazeera.com/news/2012/10/12/nigeria-flooding-called-natural-disaster.
[50] Flood takes over Anambra communities as Gov Obi cries for help. https://www.vanguardngr.com/2012/09/flood-takes-over-anambra-communities-as-gov-obi-cries-for-help/.
[51] WHO Africa (2018). Nigeria Rushes into Current Flash Flooding to Mitigate Health Hazards; World Health Organization: Geneva, Switzerland.
[52] Obeta, C.M. (2014). Institutional approach to flood disaster management in Nigeria: need for a preparedness plan. *British Journal of Applied Science & Technology*, *4*, 4575–4590.
[53] Milliman, J.D.; Syvitski, J.P.M. (1992). Geomorphic/tectonic control of sediment discharge to the ocean: the importance of small mountainous rivers. *The Journal of Geology*, *100*, 525–544. http://doi.org/10.1086/629606.
[54] Countries in the World by Population 2023. (accessed on 14 November 2023) Available online: https://www.worldometers.info/geography/countries-of-the-world/.
[55] United Nations (2022). World Population Prospects 2022; United Nations: New York, NY, USA.
[56] United Nations (2018). World Urbanization Prospects 2018; United Nations: New York, NY, USA.
[57] World Bank (2024). World Development Indicators; The World Bank: Washington, DC, USA.
[58] Urban Population (% of Total Population) - Nigeria. (accessed on 14 November 2023) Available online: http://wdi.worldbank.org/table/2.1.
[59] Caballero, P. (2014). The Niger River Delta - A Strategic Asset in Africa's Sahel; Africa Can End Poverty, World Bank Blogs: Washington, DC, USA.
[60] Meybeck, M. (1984). Les fleuves et le cycle géochimique des éléments. Thèse de Doctorat d'État, Sciences, University of Paris, Paul and Marie Curie, Paris XI, Paris, France.
[61] Development in a Changing Climate - Concept Note. (accessed on 14 November 2023) Available online: http://www.worldbank.org10.1596/978-0-8213-7987-5.
[62] Niger River. (accessed on 20 August 2026) Available online: https://www.ebsco.com/research-starters/geography-and-cartography/niger-river.
[63] Oyegun, C.U.; Lawal, O.; Ogoro, M. (2023). The Niger Delta Region. In Landscapes and Landforms of Nigeria; Faniran, A., Jeje, L.K., Fashae, O.A., Olusola, A.O., Eds.; World Geomorphological Landscapes; Springer: Cham, Switzerland. https://doi.org/10.1007/978-3-031-17972-3_7.
[64] Ocean Physics at NASA. accessed on 14 November 2023) Available online: https://science.nasa.gov/earthscience/oceanography/living-ocean.
[65] OECD (2021). Adapting to a Changing Climate in the Management of Coastal Zones; OECD Environment Policy Papers, No. 24; OECD Publishing: Paris, France. https://doi.org/10.1787/b21083c5-en.
[66] Kirezci, E.; Young, I.R.; Ranasinghe, R.; Muis, S.; Nicholls, R.J.; Lincke, D.; Hinkel, J. (2020). Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st century. *Scientific Reports*, *10*, 1–12. https://doi.org/10.1038/s41598-020-67736-6.
[67] Intergovernmental Panel on Climate Change (2023). Climate Change 2022 - Impacts, Adaptation and Vulnerability; Cambridge University Press: Cambridge, UK. https://doi.org/10.1017/9781009325844.
[68] World Bank (2018). Urban Population (% of Total Population) - Nigeria; World Urbanization Prospects, 2018 Revision; The World Bank: Washington, DC, USA.
[69] Avis, W.R. (2019). Urban Expansion in Nigeria; K4D Helpdesk Report 692; Institute of Development Studies: Brighton, UK.
[70] Saroha, J. (2018). Trends of world population growth. *International Journal of Creative Research Thoughts*, *6*, 1–8.

[71] Total population 2023. (accessed on 14 November 2023) Available online: https://geofactbook.com/fact/total-population/2023.
[72] McGranahan, G.; Satterthwaite, D. (2014). Urbanisation Concepts and Trends; IIED's Human Settlements Group: London, UK.
[73] Julius Berger (2026). Outstanding Infrastructure Project with International Significance: Second River Niger Bridge in Asaba, Nigeria; Julius Berger International GmbH: Wiesbaden, Germany.
[74] Izunwah, C. (2017). 135,000 km road network in Nigeria untarred: Otis Anyaeji and Nigerian Society of Engineers annual lecture, 2017; Infrastructure Concession Regulatory Commission: Abuja, Nigeria.
[75] Central Bank of Nigeria (2003). Highway Maintenance in Nigeria: Lessons from Other Countries; Research Department Occasional Paper No. 27; Central Bank of Nigeria: Abuja, Nigeria.
[76] Afolayan, O.D.; Abidoye, A.O. (2017). Causes of failure on Nigerian roads: a review. *Journal of Advancement in Engineering and Technology*, *4*, 1–8.
[77] NDDC (2022). NDDC Projects in Delta State; Niger Delta Development Commission: Port Harcourt, Nigeria.
[78] Kreienkamp, F.; Philip, S.Y.; Tradowsky, J.S.; Kew, S.F.; Loenz, P.; Arrighi, J.; Belleflamme, A.; Bettmann, T.; Caluwaerts, S.; Chan, S.C.; et al. (2021). Rapid Attribution of Heavy Rainfall Events Leading to the Severe Flooding in Western Europe during July 2021; World Weather Attribution, pp. 1–51.
[79] European Centre for Disease Prevention and Control (2021). Extreme Rainfall and Catastrophic Floods in Western Europe - 29 July 2021; European Centre for Disease Prevention and Control: Stockholm, Sweden.
[80] Jha, A.; Bloch, R.; Lamond, J. (2012). Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century; World Bank: Washington, DC, USA.